Evaluation of the Shaping Characteristics of ProTaper Gold, ProTaper NEXT, and ProTaper Universal in Curved Canals

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Abstract

Introduction: This study evaluated the shaping characteristics of the ProTaper Gold system (PTG; Dentsply Maillefer, Ballaigues, Switzerland) and compared it with that of the ProTaper Next (PTN, Dentsply Maillefer) and ProTaper Universal (PTU, Dentsply Maillefer) systems using micro–computed tomographic imaging. **Methods:** Twenty-four mandibular first molars with 2 separate mesial canals were matched anatomically using micro–computed tomographic scanning (SkyScan1174v2; Bruker-microCT, Kontich, Belgium) with a voxel size of 19.6 μm. Canals were prepared with PTG, PTU, or PTN rotary systems to F2 or X2 instruments, respectively, and scanned again. Coregistered images were evaluated for 2- and 3-dimensional morphometric measurements of canal transportation, centering ability, untouched canal walls, and remaining dentin thickness. Data were statistically compared using Kruskal-Wallis and 1-way analysis of variance tests (α = 5%). **Results:** Overall, PTN showed significantly higher percentage values of static voxels than PTG and PTU systems ($P < .05$). Surface area, perimeter, and minor diameter were higher in the PTG and PTU groups than in the PTN group ($P < .05$). No difference was observed in form factor, roundness, major diameter, aspect ratio, or structure model index ($P > .05$). PTG (0.11 $\pm$ 0.05 mm) and PTN (0.09 $\pm$ 0.05 mm) produced significantly less transportation than PTU (0.14 $\pm$ 0.07 mm) ($P < .05$), and the percentage decrease in dentin thickness was significantly lower for PTG (22.67 $\pm$ 2.96) and PTN (17.71 $\pm$ 5.93%) ($P \geq .05$) than PTU (29.93 $\pm$ 6.24%) ($P < .05$). **Conclusions:** PTG and PTN produced less transportation and maintained more dentin than PTU. PTN had less canal wall contact than PTG and PTU, but all file systems were able to instrument moderately curved mesial root canals of mandibular molars without clinically significant errors. *(J Endod 2015;41:1718–1724)*

Key Words

Canal transportation, micro–computed tomographic imaging, multiple-file system, nickel-titanium instruments, root canal preparation, rotary instruments

Apical periodontitis is caused by root canal infection (1). Its treatment is focused on the elimination of microorganisms by chemomechanical preparation of the root canal (2, 3). Nickel-titanium (NiTi) rotary instruments used for this purpose produce a more centered preparation of the canal, with less transportation than stainless steel instruments (4). NiTi rotary instrument designs continue evolving to optimize their cutting and shaping characteristics. With many new systems available on the market, clinicians require an impartial evaluation of these systems' characteristics to help them select systems to use clinically.

ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) is a relatively new system. PTN instruments are made of M-wire, a unique NiTi alloy manufactured by a thermal treatment process that reportedly increases flexibility and resistance to cyclic fatigue (5, 6). These instruments incorporate a variable regressive taper design, unique offset mass of rotation, and rectangular cross section, which according to the manufacturer are designed to reduce points of contact with the canal walls generating less fatigue in the instrument during use.

ProTaper Universal (PTU, Dentsply Maillefer) and ProTaper Gold (PTG, Dentsply Maillefer) systems share an identical instrument design with a triangular cross section and a variable progressive taper. PTG is manufactured by proprietary metallurgy that reportedly increases its flexibility and its resistance to cyclic fatigue (7). To our knowledge, research data on the shaping characteristics of PTG were not yet available at the time this study was undertaken. Thus, this study aimed to evaluate the shaping characteristics of the PTG system and compare it with that of the PTN and PTU systems using micro–computed tomographic (micro-CT) imaging.

Materials and Methods

Tooth Specimen Selection and Groups

The study protocol was approved by the University of Toronto Research Ethics Board (protocol reference #29482). One hundred fifty permanent mandibular first molars with 2 moderately curved mesial canals (25°–35°) were selected. Teeth were imaged with cone-beam computed tomographic imaging (Kodak 9000; Carestream Dental LLC, Atlanta, GA) set at 66 kV, 10 mA, 10.8-second exposure, and a slice thickness of 76 μm to obtain a pretreatment outline of the root canals. Twenty-four teeth with 2 independent patent mesial canals were selected for further study. These were

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decoronated slightly above the cementoenamel junction, disinfected in 0.5% chloramine T solution, and stored in distilled water at 4°C.

Before instrumentation, teeth were mounted on a custom attachment and imaged using a micro-CT system (SkyScan 1174v2: Bruker-microCT, Kontich, Belgium) at 50 kV and 800 μA and an isotropic resolution of 19.6 μm. Scanning was performed through 180° rotation around the vertical axis with a rotation step of 1° using a 0.5-mm-thick aluminum filter. The acquired images were reconstructed into cross-sectional slices with NRecon v.1.6.9 software (Bruker-microCT) using standardized parameters for beam hardening (15%), ring artifact correction (5%), and similar contrast limits. The volume of interest was selected extending from the furcation level to the apex of the root, resulting in the acquisition of 700 to 900 transverse cross sections per tooth in a bitmap (BMP) format. Root canal length, volume, surface area, and dentin thickness from the level of the furcation to the apex of the root were recorded using CTAn v.1.14.4 software (Bruker-microCT, Kontich, Belgium). Sample size calculation indicated that 16 root canals per group were required to support analysis with 80% power and 5% level of significance (8, 9).

Subsequently, 24 mesial roots (48 root canals) were matched to create 8 groups of 3 roots based on the 3-dimensional (3D) morphologic aspects of the mesial canals. One root from each group was randomly assigned to 1 of the 3 experimental groups (n = 16) according to the canal preparation systems (ie, PTG, PTU, or PTN). After checking the normality assumption (Shapiro-Wilk test), the degree of homogeneity (baseline) of the 3 groups with respect to canal length, volume, and surface area was confirmed using the 1-way analysis of variance test with a significance level of 5% (α = .05).

Root Canal Preparation

A single experienced operator performed all procedures. Canals were accessed and the coronal third flared with Gates-Glidden drills 2 and 3 (Dentsply Maillefer). Apical patency was confirmed with a #10 K-type file (Dentsply Maillefer) passed through the apical foramen before and after canal preparation. The working length (WL) was determined by passing a #10 K-type file through the major foramen and withdrawing it 0.5 mm. A glide path was created using a ProGlider instrument (16/02) (Dentsply Maillefer) carried to the WL. All instruments used were taken to the WL in a continuous clockwise rotation generated by a 6:1 angle handpiece (Sirona, Bensheim, Germany) powered by an electric motor (VDW Silver Motor; VDW GmbH, Munich, Germany) at 300 rpm and 2.5 Ncm. The instrument sequence in the PTU and PTG groups was S1 (17/02), S2 (20/04), F1 (20/07), and F2 (25/08). In the PTN group, the sequence was X1 (17/04) and X2 (25/06). After 3 gentle in-and-out motion strokes in an apical direction, the instrument was removed from the canal and cleaned. This was repeated until the WL was reached, and then the instrument was discarded. After each step, the canal was irrigated with 20 mL 2.5% NaOCl using a disposable syringe fitted with a 30-G NaviTip needle (Ultradent, South Jordan, UT) placed 1 mm short of the WL. A final rinse with 5 mL 17% EDTA was followed by a 5-mL rinse with distilled water. Canals were dried with paper points (Dentsply Maillefer), imaged with a micro-CT system, and reconstructed with the same parameters used in pretreatment scans.

Outcome Measures

Color-coded 3D models of the root canals, pre- and post-preparation, were coregistered using automated image registration. Custom combinations of rigid to affine modules were used based on image intensity similarities (3D Slicer 4.3.1 software, available from http://www.slicer.org) with accuracy greater than 1 voxel. Unprepared (green) and prepared (red) matched canals were qualitatively compared using CTVol v.2.2.1 software (Bruker-microCT). The area of untouched canal surface was determined by calculating the number of static voxels (voxels present in the same position on the canal surface before and after instrumentation). The untouched area was expressed as a percentage of the total number of voxels present on the canal surface (10).

CTAn v.1.14.4 software was used to measure volume (in mm^3), surface area (in mm^2), structure model index (SMI), area (in mm^2), perimeter (in mm), form factor, roundness, major diameter (in mm), minor diameter (in mm), and aspect ratio of the root canals before and after preparation. 3D evaluation was performed for the full canal length, and 2-dimensional (2D) evaluation was done for the apical 5 mm of the canal in 250 cross-sectional images per canal. Comparison parameters were calculated by subtracting values obtained for treated canals with those obtained from untreated counterparts. Criteria used for the calculation of the parameters have been published previously (10–12).

Canal transportation was assessed from a center of gravity calculated for each slice and connected along the z-axis with a fitted line through a total of 8583 cross sections in the PTU group, 8345 in the PTN group, and 8477 in the PTG group using XLSTAT-3DPlot for Windows (Addinsoft, New York, NY). The mean transportation (mm) was calculated by comparing the centers of gravity before and after treatment for the coronal, middle, and apical thirds of the canals.

The mean percentage decrease of dentin wall thickness was acquired by the superimposition of the data sets before and after canal preparation from the midpoint between the canal orifice and the foramen. Fifteen measurements of the width of dentin toward the distal aspect of the external root surface, perpendicular to a line connecting the centers of gravity, spaced by 1° in either the mesiobuccal or mesiolingual canals were recorded. Color-coded 3D models of dentin thickness throughout the root were created by CTAn v.1.14.4 software.

The Shapiro-Wilk test was used to assess the normality of the data. Results of untouched canal wall surface, volume, surface area, SMI, area, perimeter, roundness, form factor, major and minor diameters, and aspect ratio were compared between groups using the Kruskal-Wallis post hoc Dunn test and presented as median values or an interquartile range (IQR). Canal transportation and dentin wall thickness data were normally distributed and compared between groups with the 1-way analysis of variance post hoc Tukey test. Commercially available software (SPSS v17.0; SPSS Inc, Chicago, IL) was used for analysis at a 5% significance level.

Results

The median and IQR of static voxels indicating an untouched canal surface in each group are shown in Figure 1. A wide range in calculated percentages (0%–34%) was noted among specimens within groups; however, the analysis of the values recorded indicated that for most specimens the variance ranged from 6%–13%. Overall, the PTN group showed significantly higher ($P < .05$) median percentage values of static voxels (11.66%, IQR = 11.94) when compared with the PTG (3.57%, IQR = 9.92) and PTU (2.66%, IQR = 7.83) groups. No significant difference was noted between PTG and PTU.

The results of the 2D and 3D analyses are shown in Tables 1 and 2, respectively. Preparation significantly increased all measured parameters in each group. Overall, the percentage increase in the surface area, the perimeter, and the minor diameter of the canals were significantly higher in the PTG and PTU groups than in the PTN group ($P < .05$). No statistical difference in form factor, roundness, major diameter, aspect ratio, or SMI was present among groups

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